INDOOR AIR QUALITY ASSESSMENT

Samuel Bowles Elementary School
Bowles Park
Springfield, Massachusetts

Prepared by:
Massachusetts Department of Public Health
Bureau of Environmental Health Assessment
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Background/Introduction

At the request of Principal Sandra Vella, the Massachusetts Department of Public Health (MDPH), Bureau of Environmental Health Assessment (BEHA) provided assistance and consultation regarding indoor air quality at the Samuel Bowles School, Bowles Park, Springfield, Massachusetts. Concerns about symptoms of headache, irritated eyes, tiredness and a suspected increase in the prevalence of illness among building occupants prompted this request.

On October 25, 2001, a visit was made to this school by Michael Feeney, Chief of Emergency Response/Indoor Air Quality (ER/IAQ), BEHA, to conduct an indoor air quality assessment.

The school is a three-wing, two-story brick structure that was built in two stages. The original school building was constructed in 1926 (see Picture 1). A wing was added to the building in 1954 (see Picture 2). A third wing was added in the early 1960s (see Picture 3). Windows are openable throughout the building. The 1925 building has windows that tilt (see Picture 4). The 1956 and 1960s wings have a combination of hopper and awning windows (see Pictures 5 and 6).

Methods

Air tests for carbon dioxide, temperature, relative humidity and carbon monoxide were taken with the TSI, Q-Trak ™, IAQ Monitor Model 8551.

Results

The school has a student population of 415 and a staff of approximately 60. Tests were taken during normal operations at the school and results appear in Tables 1-3.

Discussion

Ventilation

It can be seen from the tables that carbon dioxide levels were elevated above 800 parts per million parts of air (ppm) in nine of twenty-nine areas surveyed, indicating a ventilation problem in some areas of the school. It should be noted however, that a number of areas with carbon dioxide levels below 800 ppm either had open windows or were sparsely populated, which can greatly contribute to the reduction of carbon dioxide levels. Please note a number of classrooms had carbon dioxide levels *above 800 ppm with windows open.* Increased carbon dioxide measurements can indicate that outdoor airflow provided by open windows alone may not be sufficient to provide adequate ventilation. At the time of this assessment, the ventilation system in a number of classrooms was deactivated, which would limit the introduction of fresh air into the building and contribute to increasing carbon dioxide levels. Carbon dioxide levels in the building would be expected to increase over comfort levels during winter months when windows and exterior doors are closed due to the configuration and condition of the ventilation system.

Each wing is outfitted with different types of ventilation systems. Fresh air in the 1925 section of the building (except the basement classrooms) is provided by a unit ventilator (univent) system of a design dating back to the original construction of the building (see Picture 7, Figure 1). Within each univent is a fan. Opposite the fan is a set of moveable louvers through which fresh air enters the univent. Controlling the amount of fresh air drawn into each univent is a sliding panel (see Picture 8). If the panel is slid to cover the return air vent entirely, the univent will draw 100 percent fresh air. Return air can be added as the panel is slid open. In order for univents to function as designed, univent fresh air diffusers and return vents must be unblocked and remain free of obstructions. Importantly, these units must be activated and allowed to operate.

Exhaust ventilation is drawn from the 1925 classrooms (and room B) into an ungrated hole located at floor level. A flue located inside the duct controls airflow. Exhaust ventilation is provided by one of two methods in a building of this age and design: 1) a natural gravity vent, which uses a heating element to create an updraft (i.e., the stack effect) to create ventilation or 2) a mechanical exhaust ventilation fan powered by a rooftop motor (see Picture 9). It is likely that a mechanical exhaust vent system exists, since classroom B has a duct equipped with a handle connected to a louver that controls exhaust airflow. The metal duct is not insulated to prevent heat transfer from a heating element; thus it is likely that this vent is mechanical or is connected to a frozen turbine fan (see Picture 10) located on the roof. In either case, this system was either drawing very weakly or was deactivated. A number of these vents were obstructed with baskets, file cabinets, shelves or other classroom materials. These vents must remain clear of obstructions in order to function as designed.

The 1954 and 1960s sections of the building (and classroom B) have fresh air provided by a univent system of a design dating back to the construction of the wing (see Picture 11, Figure 2). As with the older models, within each univent is a fan. Univents draw air from outdoors through a fresh air intake located on the exterior walls of the building and return air through an air intake located at the base of each unit. The mixture of fresh and return air is drawn through a filter and a heating coil, and is then expelled from the univent by motorized fans through fresh air diffusers. Univents were deactivated in some classrooms. In order for univents to function as designed, univent fresh air diffusers and return vents must be unblocked and remain free of obstructions. Importantly, these units must be activated and allowed to operate.

The 1956 wing has an exhaust ventilation system that is different from the 1925 wing. Exhaust ventilation in these classrooms is provided by a unit exhaust ventilator. Unit exhaust ventilators have fans similar to univents that draw air from an area and remove it from the building through a vent on the exterior wall (see Picture 12). Most unit exhaust ventilators were not operating during the assessment, indicating that they may be broken, deactivated or cycling (operating when a preset temperature is measured by the classroom's thermostat).

Exhaust ventilation in the 1960s wing consists of wall-mounted vents connected to rooftop exhaust motors via ductwork (see Picture 13). No draw of air was noted in these vents, indicating that the exhaust fans are either broken or deactivated.

A number of areas (classroom A, school adjunct counselor office, the main office and principal's office) have neither mechanical supply nor exhaust ventilation. Ventilation is provided by opening windows or doors. Some windows in these areas are painted shut and cannot be opened.

To maximize air exchange, the BEHA recommends that both supply and exhaust ventilation operate continuously during periods of school occupancy. In order to have proper ventilation with a mechanical supply and exhaust system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. The date of the last servicing and balancing was not available at the time of the assessment. It is recommended that existing ventilation systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994).

The Massachusetts Building Code requires a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows in each room (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

The Department of Public Health uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches.

Temperature readings (ranging from 72^{o} F to 81^{o} F) were close to the BEHA recommended comfort guidelines. The BEHA recommends that indoor air temperatures be maintained in a range of 70^{o} F to 78^{o} F in order to provide for the comfort of building occupants. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply. Temperature control is often difficult in an old building without a functioning ventilation system and/or the system not working as designed.

The relative humidity was measured in a range of 50 to 67 percent. Many areas sampled were above the BEHA recommended comfort range. The BEHA recommends a comfort range of 40 to 60 percent for indoor air relative humidity. All areas measured had relative humidity measurements 5 to 22 percent higher than the relative humidity measured outdoors (45%) on the day of the assessment. This increase in relative humidity can indicate that the exhaust system alone is not operating sufficiently to remove normal indoor air pollutants (e.g., water vapor from respiration). Moisture removal is important since the sensation of heat increases as relative humidity increases (the relationship between temperature and relative humidity is called the heat index). As indoor temperature rises, the addition of more relative humidity will make occupants feel hotter. If moisture is removed, the comfort of the individuals is enhanced. Removal of moisture from the air, however, can have some negative effects. The sensation of dryness and irritation is common in a low relative humidity environment. Humidity is more difficult to control during the winter heating season. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

Classroom A in the basement had water-damaged wall plaster, indicating leaks from plumbing in the restrooms on the first floor (see Picture 14). Water-damaged wall plaster can provide a medium for mold and mildew growth, especially if wetted repeatedly. These materials should be repaired/replaced after a water leak is discovered.

A number of exterior wall conditions would tend to make the building susceptible to water penetration from rain. Some brickwork on the north exterior wall of the 1925 wing is missing mortar (see Picture 15). Damaged exterior brick can lead to increased water penetration that can damage window frames and interior plaster.

The south wall of the cafeteria shows signs of efflorescence (i.e. mineral deposits) (see Picture 16). Efflorescence is a characteristic sign of water intrusion. As moisture penetrates and works its way through mortar around brick it leaves behind mineral deposits. This condition indicates that water from the exterior is penetrating into the building.

Shrubbery, in close proximity to the exterior wall brick, was noted in several areas around the building. Shrubbery can serve as a possible source of water impingement on the exterior curtain wall due to the location of plants and tree branches growing directly against the building. Plants retain water and, in some cases, can work their way into mortar and brickwork causing cracks and fissures, which may subsequently lead to water penetration and possible mold growth. In addition, the growth of roots against the exterior walls can bring moisture in contact with wall brick and eventually lead to cracks and/or fissures in the foundation below ground level. Over time, this process can undermine the integrity of the building envelope and provide a means of water entry into the building through capillary action in foundation concrete and masonry (Lstiburek & Brennan, 2001).

Other Concerns

A number of other conditions that can potentially affect indoor air quality were also observed. Several classrooms contained excessive chalk dust. Chalk dust can easily become aerosolized and serve as an eye and respiratory irritant. The teacher's workroom contained a photocopier. Volatile organic compounds (VOCs) and ozone can be produced by photocopiers, particularly if the equipment is older and in frequent use. Ozone is a respiratory irritant (Schmidt Etkin, 1992). No mechanical exhaust ventilation is provided in this area. Without mechanical exhaust ventilation, excess heat, odors and pollutants produced by office equipment can build up and lead to indoor air quality complaints.

Of note is the use of different products containing volatile organic compound (VOC) in the building. Materials such as rubber cement, permanent markers, dry erase markers and liquid correction fluid were observed in a number of classrooms. These materials may contain volatile organic compounds, which can be irritating to the eyes, nose and throat and, in some cases, extremely flammable. Local exhaust ventilation should be utilized when these products are used.

Under the Labeling of Hazardous Art Materials Act (LHAMA), art supplies containing hazardous materials that can cause chronic health effects must be labeled as required by federal law (USC, 1988). The use of art supplies containing hazardous materials that can cause chronic health effects should be limited to times when students are not present and only when adequate exhaust ventilation is available.

No means for installing filters in univents in the 1925 wing could be identified. In this condition, dust, dirt and other debris can be introduced/re-aerosolized by the ventilation system. In order to decrease aerosolized particulates, disposable filters with a high dust spot efficiency should be installed. The dust spot efficiency is the ability of a filter to remove particulates of a certain diameter from air passing through the filter. Filters that have been determined by ASHRAE to meet its standard for a dust spot efficiency of a minimum of 40 percent would be sufficient to reduce airborne particulates (Thornburg, 2000; MEHRC, 1997; ASHRAE, 1992). Note that increased filtration can reduce airflow produced by the unit due to increased resistance (called pressure drop). Prior to any increase of filtration, each univent should be evaluated by a ventilation engineer to ascertain whether it can maintain function with higher efficiency filters.

A fireplace exists in the library (see Picture 17) which appeared to be no longer in use. The chimney for the fireplace exists on the roof (see Picture 18). The top of the chimney is open, which can allow rainwater to penetrate down the shaft. In addition, animals may also enter the building through the chimney.

A door exists outside classroom A that leads to a crawlspace used for storage. This door is not airtight. Air from the crawlspace can penetrate into the classroom and distribute dust, dirt and other pollutants into occupied spaces. A pipe in classrooms A (see Picture 19) and an abandoned duct in classroom B (see Picture 20) were noted penetrating interior walls. Each of these abandoned building components may serve as pathways for dust, dirt and other debris to penetrate into basement classrooms.

The building has means for pests to penetrate into the building. A hole exists in an exterior door for the 1960s wing (see Picture 21). To penetrate the exterior of a building, rodents require a minimal breach of ¼ inch (MDFA, 1996). Rodent infestation results from easy access to food and water in a building. Rodent infestation can result in indoor air quality related symptoms due to materials in their wastes. Mouse urine contains a protein that is a known sensitizer (US EPA, 1992). A three-step approach is necessary to eliminate rodent infestation:

1. removal of rodents;
2. cleaning of waste products from the interior of the building;
3. reduction/elimination of pathways/food sources that are attracting rodents.

To eliminate exposure to allergens, rodents must be removed from the building. Please note that removal, even after cleaning, may not provide immediate relief since allergens can exist in the interior for several months after rodents are eliminated (Burge, 1995). A combination of cleaning, and increasing ventilation and filtration should serve to reduce rodent associated allergens once the infestation is eliminated. Under current Massachusetts law effective November 1, 2001, the principles of integrated pest management (IPM) must be used to remove pests in schools (Mass Act, 2000).

An open pipe elbow with exposed insulation was found in the basement classrooms (see Picture 22). A determination should be made as to whether the insulation material contains asbestos. If so, it should be remediated in conformance with all applicable Massachusetts asbestos abatement and hazardous materials disposal laws.

Conclusions/Recommendations

The conditions noted at the Bowles Elementary School raise a number of issues. The combination of the design of the building and the condition of the ventilation system can adversely influence indoor air quality. For these reasons a two-phase approach is required, consisting of **(short-term)** immediate measures to improve air quality and **(long-term)** measures that will require planning and resources to adequately address overall indoor air quality concerns. In view of the findings at the time of the visits, the following **short-term** recommendations are made:

1. Survey classrooms for univent function to ascertain if an adequate air supply exists for each room and make univent repairs as needed. Consider consulting a heating, ventilation and air conditioning (HVAC) engineer concerning the calibration of univent fresh air control dampers school-wide.
2. Operating the univent system in all areas of the building during hot weather will supplement the use of open windows. If sections of the ventilation system do not operate, the placement of fans to exhaust air from the leeward side (opposite the windward side) of a building with open hallway doors may be employed. With this type of ventilation system, univents should be operating during school hours with

the fresh air damper open 100% to enhance airflow into classrooms. This converts each univent into a large fan system.

3. Examine the unit exhaust ventilators for function. If broken, repair. Operate each of these units in concert with univents.
4. Repair frozen turbine exhaust vent on roof.
5. To maximize air exchange, the BEHA recommends that univents and exhaust vents operate continuously during periods of school occupancy independent of classroom thermostat control.
6. Cut back shrubbery a minimum of three feet to prevent water impingement on exterior brickwork.
7. Seal the abandoned library chimney at roof level to prevent rainwater penetration and animal egress.
8. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a high efficiency particulate arrestance (HEPA) filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended. Avoid the use of feather dusters. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).
9. Repair/replace water damaged plaster, examine surrounding non-porous areas for mold growth and disinfect with an appropriate antimicrobial if necessary.

10. Clean chalkboards and trays regularly to prevent the build-up of excessive chalk dust.
11. Seal the seams in crawlspace access doors with weather-stripping and a door sweep.
12. Seal all abandoned pipes and ducts in basement classrooms.
13. Implementation of the principles of integrated pest management (IPM) is highly recommended for the removal of pests. A copy of the IPM recommendations are included with this report as (MDFA, 1996).
14. Ascertain whether the pipe wrap in Picture 21 contains asbestos and, if so, encapsulate or remove in conformance with Massachusetts law.

The following **long-term** measures should be considered.

1. *A ventilation engineer should be consulted to resolve air supply/exhaust ventilation building-wide*
2. Consideration should be given to replacing univents with an HVAC system that provides fresh, filtered outdoor air.
3. Consider installing a local mechanical exhaust fan for the photocopier to remove excess heat and odors.
4. Examine the feasibility of providing fresh air supply and exhaust ventilation to areas without a mechanical means of ventilation.
5. Repair and/or replace thermostats and pneumatic controls as necessary to maintain control of thermal comfort. Consider contacting an HVAC engineer concerning the repair and calibration of thermostats and pneumatic controls school-wide.

6. Consider having exterior brick re-pointed to prevent further moisture penetration and subsequent water damage.
7. Obtain blueprints (if available) of the original building to determine the configuration of the exhaust ventilation in the 1925 wing. Once the configuration is identified, consider consulting a ventilation engineer concerning the best method to reactivate exhaust ventilation in this wing.

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Figure 1 **Unit Ventilator (Univent)**

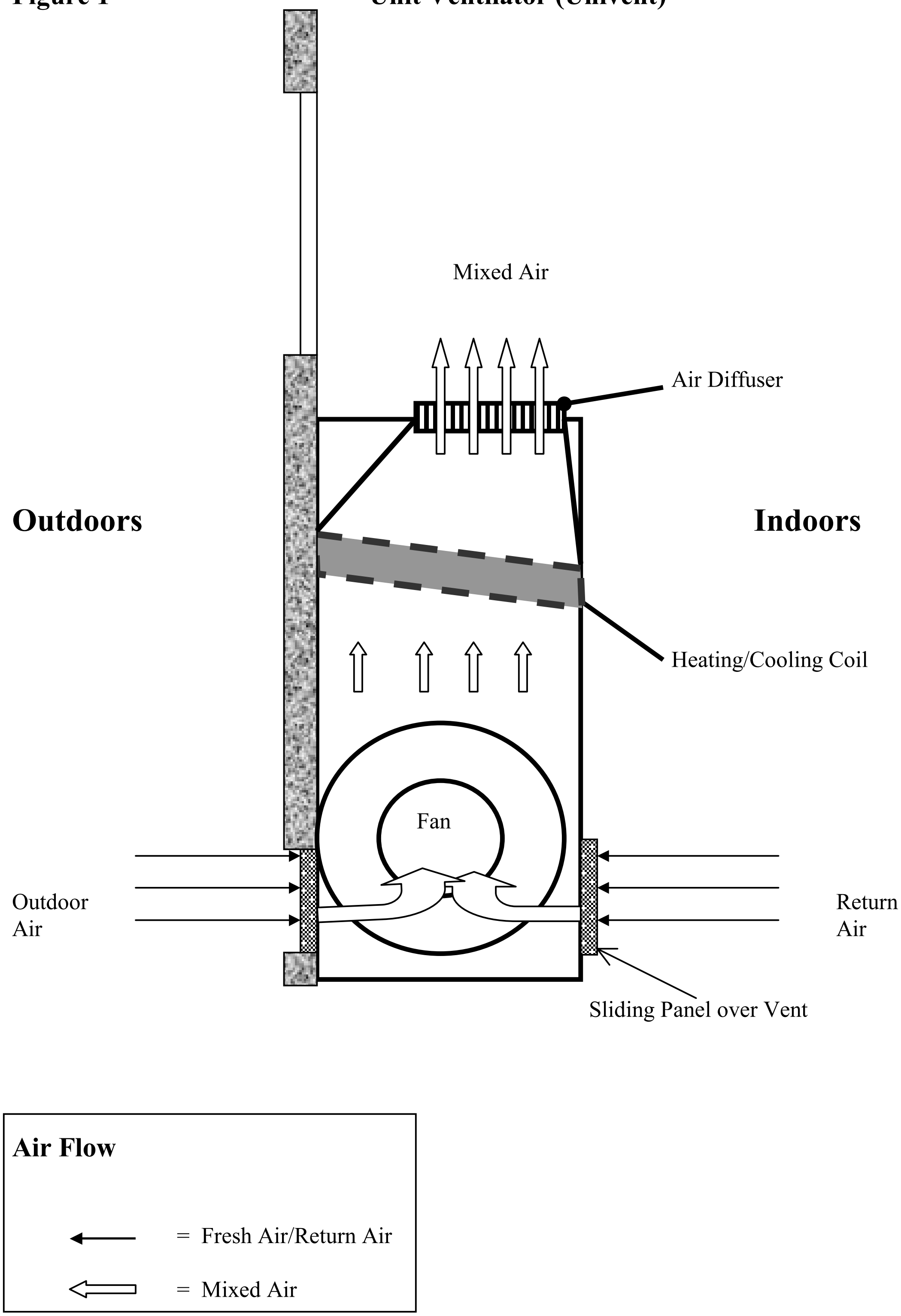
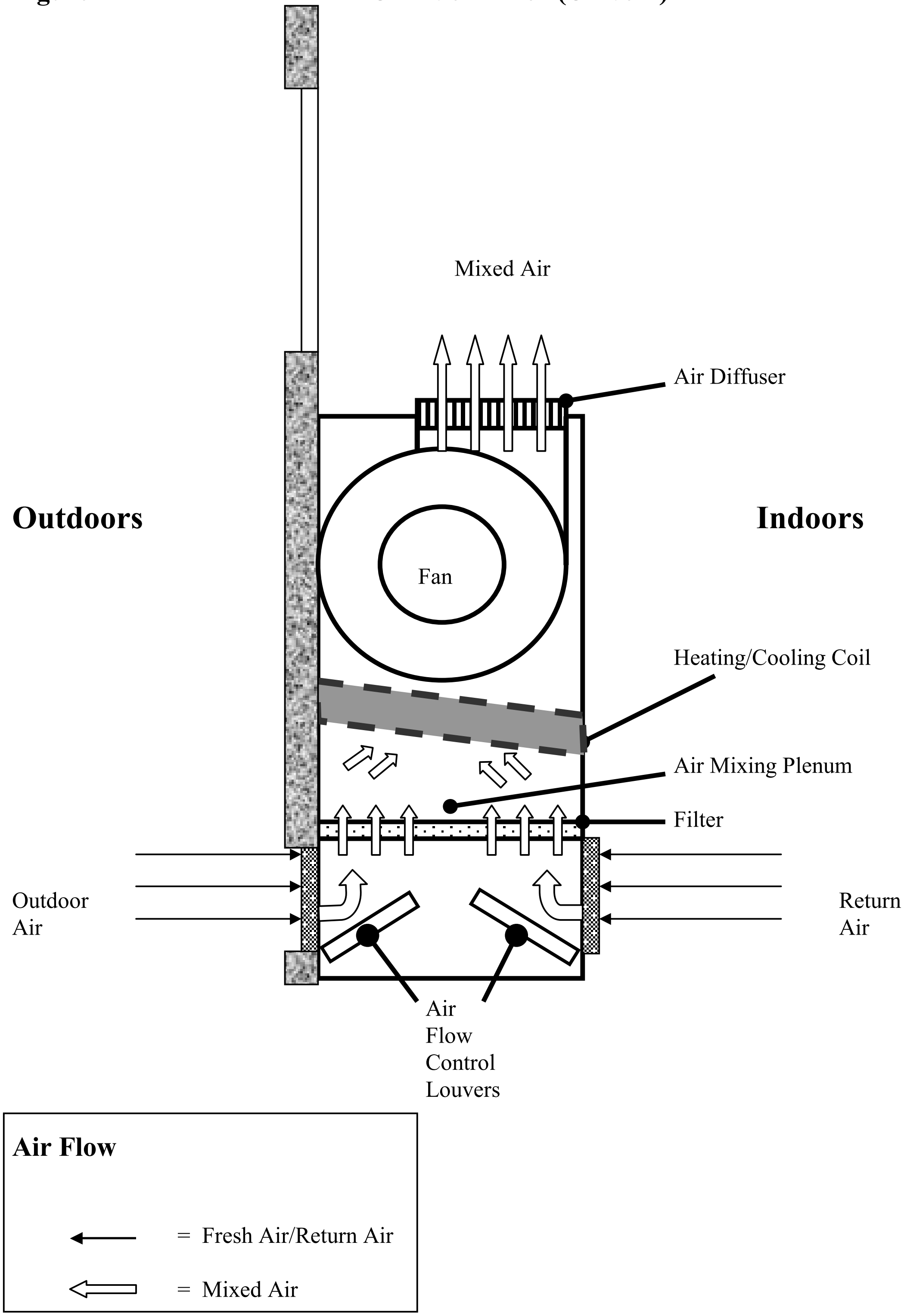


Figure 2 **Unit Ventilator (Univent)**



Picture 1

Original School Building

Picture 2

1954 Wing

Picture 3

1960s Wing

Picture 4

Tilting Windows of the 1925 Wing

Picture 5

Awning Windows in the 1956 Wing

Picture 6

Hopper Windows in the 1960s Wing

Picture 7

Univent in the 1925 Wing

Picture 8

Sliding Panel on Return Vent of the 1925 Wing Univents

Picture 9

Housing for Possible Mechanical Exhaust Ventilation Fan on the 1925 Wing Roof

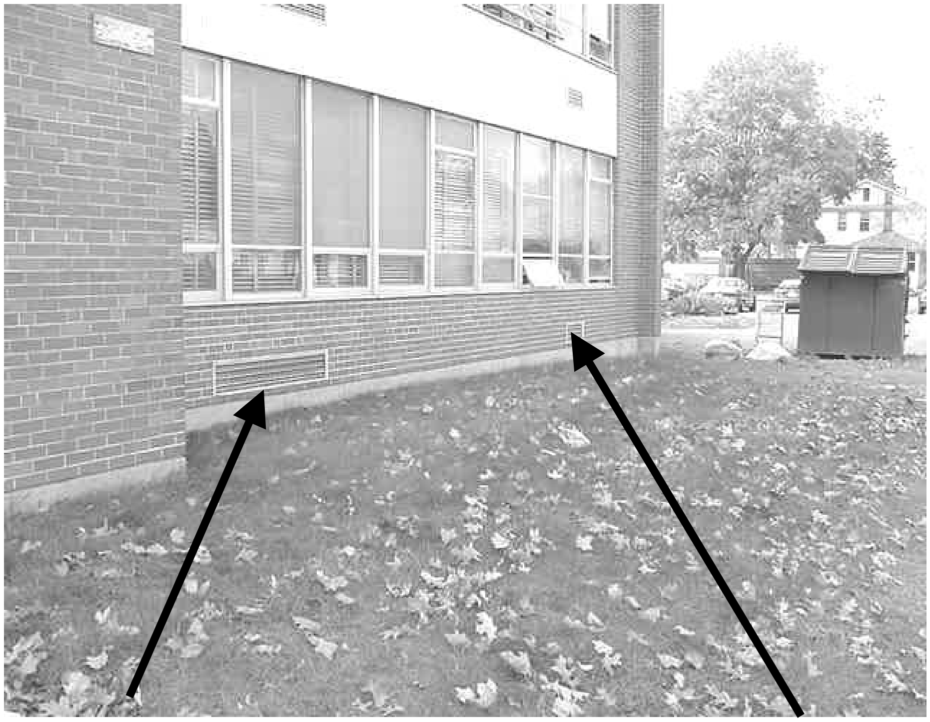
Picture 10

Frozen Turbine Fan on the 1925 Wing Roof

Picture 11

Univent Installed in Classroom B

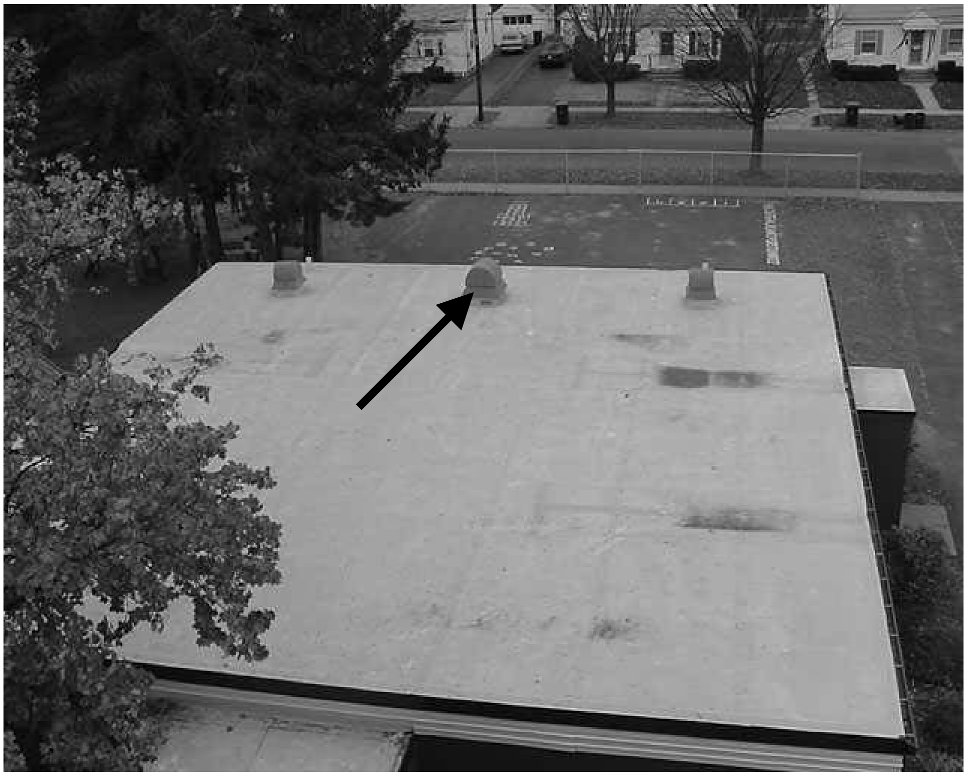
Picture 12



Fresh Air Intake Exhaust Vent

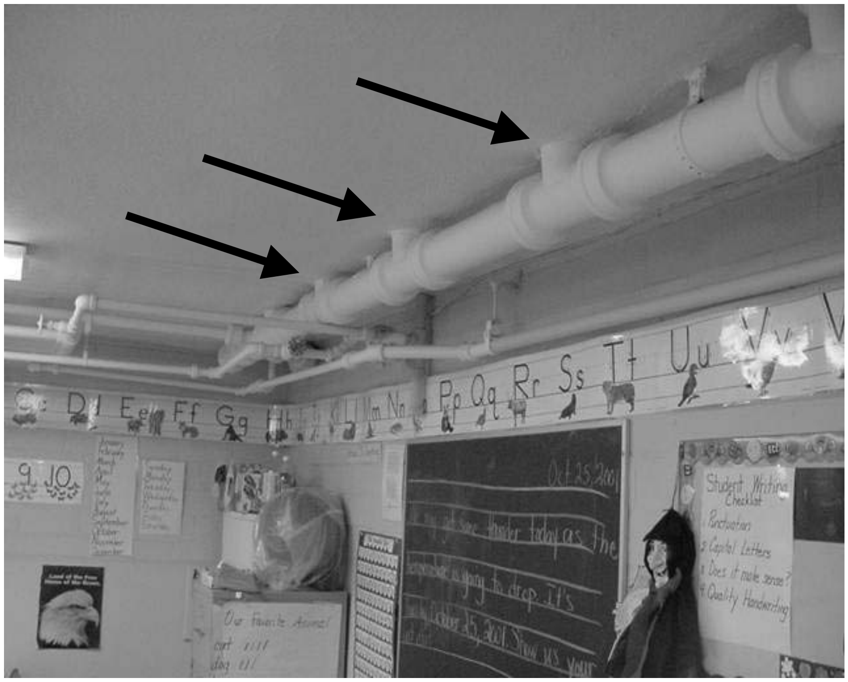
Fresh Air Intake and Exhaust Unit Ventilator Grill

Picture 13



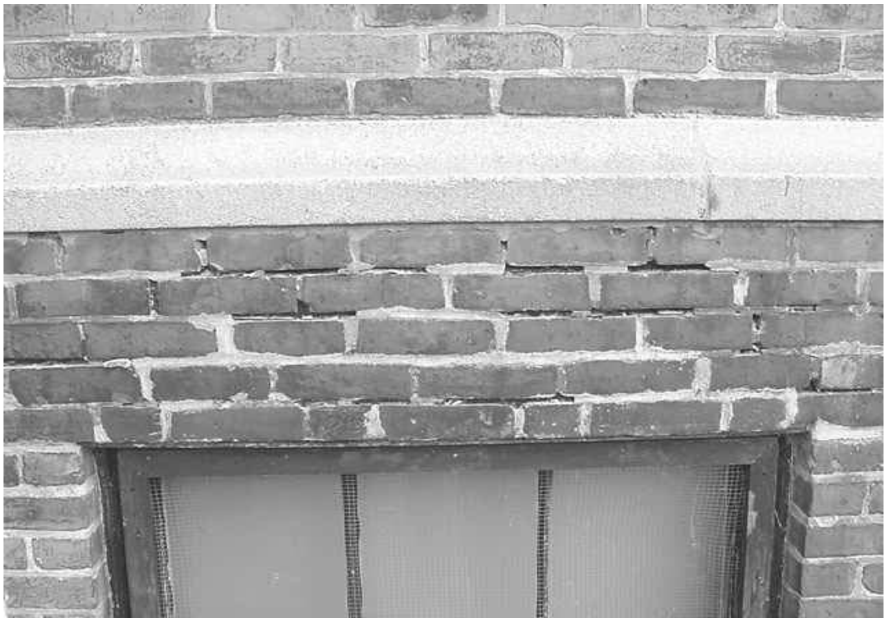
Exhaust Vent Terminus on the 1960s Wing Roof

Picture 14



Water Damaged Ceiling Plaster around Restroom Drain Pipes in Classroom A

Picture 15



Missing Brick Mortar on North Exterior Wall of 1925 Wing

Picture 16

Efflorescence on Cafeteria Wall

Picture 17

Unused Fireplace in the Library

Picture 18

Chimney for Library Fireplace

Picture 19

Open Pipe in Classroom A

Picture 20

Abandoned Duct in Classroom B

Picture 21

Hole in 1960s Wing Exterior Door

Picture 22

Open Pipe Wrap Elbow in Classroom A

TABLE 1

Indoor Air Test Results – Samuel Bowles Elementary School, Springfield, MA – October 25, 2001

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
Outside (Background)	375	77	45					
Cafeteria	782	80	58	60+	No	Yes	Yes	Efflorescence, outside door open
Room 18	614	78	54	2	Yes	Yes	Yes	Window open, univent off, unit exhaust ventilator
Room 16	741	78	57	18	Yes	Yes	Yes	Window open, univent off, unit exhaust ventilator
Main Office	641	80	52	1	Yes	No	No	Photocopier, outside door open
Principal's Office	557	79	53	1	No	No	No	Outside door/hallway door open
Room 17	1030	79	54	22	Yes	Yes	Yes	Window open, exhaust vent. Off
Room A	921	76	50	6	Yes	No	No	Window and door open, open elbow, ***
Room 9	570	77	62	16	Yes	Yes	Yes	Window and door open, univent off, water damaged plaster
Room 12	958	77	60	19	Yes	Yes	Yes	Window open, univent off-obstructed by shelf, exhaust obstructed by file cabinet

*** ppm = parts per million parts of air**
CT = ceiling tiles

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
	600 - 800 ppm = acceptable
	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

TABLE 2

Indoor Air Test Results – Samuel Bowles Elementary School, Springfield, MA – October 25, 2001

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
Room 8	554	77	60	14	Yes	Yes	Yes	Window open, univent off, exhaust obstructed by basket
Room 13	597	76	58	14	Yes	Yes	Yes	Window open, univent off, exhaust obstructed by box
Room 7	575	77	60	18	Yes	Yes	Yes	Window open, univent off, exhaust obstructed by materials
Room 19	1221	79	60	11	Yes	Yes	Yes	Window open, unit exhaust ventilator off
Room 20	737	79	58	17	Yes	Yes	Yes	Window and door open, exhaust obstructed by shelf
Room D	1146	80	58	14	Yes	No	No	Window open, passive door vent, floor fan
Room 21	722	79	59	20	Yes	Yes	Yes	Window and door open, univent off, unit exhaust ventilator
School Adjunct Counselor's Office	822	80	54	1	Yes	No	No	Door vent
Faculty Room	846	81	56	11	Yes	No	Yes	Window and door open, door vent
Room B	722	72	61	5	No	Yes	Yes	Univent off-painted shut-no filter change, holes in wall, door open, floor drain, ***

*** ppm = parts per million parts of air**
CT = ceiling tiles

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
	600 - 800 ppm = acceptable
	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

TABLE 3

Indoor Air Test Results – Samuel Bowles Elementary School, Springfield, MA – October 25, 2001

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation Intake	Ventilation Exhaust	Remarks
Room 14B	788	74	67	31	Yes	Yes (3)	Yes	Window and door open, 3 univents-off, exhaust off
Room 15	1190	74	62	27	Yes	Yes	Yes	Window open, exhaust off
Room 4	510	75	63	11	Yes	Yes	Yes	Window and door open, univent off, exhaust vent louver frozen open, permanent marker, liquid paper, exposed fiberglass
Room 5	843	75	60	0	Yes	Yes	Yes	Univent off, exhaust obstructed by cabinet-louver shut, door open
Room 3	434	75	63	3	Yes	Yes	Yes	Window open, univent off, exhaust obstructed by box
Room 2 – Library	633	76	62	37	Yes	Yes (2)	Yes	Window and door open, 2 univents off-plants on univent, exhaust obstructed by table/TV
Room 6	765	76	64	17	Yes	Yes	Yes	Window open, univent off, exhaust obstructed by cabinet, scented markers
Room 10	532	76	62	17	Yes	Yes	Yes	Window and door open, univent off, antibacterial cleaner/furniture polish

*** ppm = parts per million parts of air**
CT = ceiling tiles

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
	600 - 800 ppm = acceptable
	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

TABLE 4

Indoor Air Test Results – Samuel Bowles Elementary School, Springfield, MA – October 25, 2001

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
Room 11	691	76	61	21	Yes	Yes	Yes	Window open, univent off, exhaust obstructed by desk

*** ppm = parts per million parts of air**
CT = ceiling tiles

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
	600 - 800 ppm = acceptable
	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%